

TEST OF A HARRINGTON  
CHAIN GRATE STOKER

BY

R. REGENSBURGER

J. M. STONE

W. N. ERICKSON

P. J. ADAM

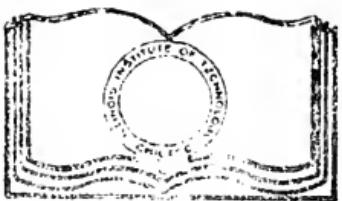
I. J. BREADY

ARMOUR INSTITUTE OF TECHNOLOGY

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# PERFORMANCE AND EFFICIENCY TEST OF A HARRINGTON CHAIN GRATE STOKER

## A THESIS

PRESENTED BY

R. REGENSBURGER    J. M. STONE    W. N. ERICKSON  
P. J. ADAM       I. J. BREADY

TO THE

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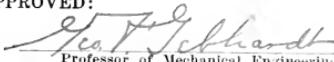
ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

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IN  
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APPROVED:

  
G. V. Ichhardt  
Professor of Mechanical Engineering

  
Dean of Engineering Studies

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A HARRINGTON CHAIN GRATE STOKER.



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## PART ONE.

Which includes a preliminary discussion and outline of the subject matter, the purpose of the work, the method of procedure, and the final results.



Performance and Efficiency Test of a  
Harrington Chain Grate Stoker.

Introduction.

Until recently the efficiency of our American power plants has been of secondary consideration. With the once vast beds of coal, slowly but inevitably being exhausted, and the consequent steady increase in fuel cost, this question of economy and boiler efficiency is now paramount in modern plants.

One of the great losses in the conversion of heat to either mechanical or electrical energy is in the boiler. Subdividing the boiler losses, and excluding those which are inherent and caused by radiation, the governing efficiency factor is the boiler setting, which includes the combustion chamber and the grate.

There are few engineering problems which contain more variables than does the one of proper combustion under a steam boiler. However, as all these are common knowledge no space will be devoted here to a further discussion. Suffice to say that a correctly



designed grate in a proper setting is the first step towards higher boiler efficiency. In all the larger installations some form of mechanical stoker is used and with few exceptions is integral with the grate. Perhaps the most common form of stoker, for free burning bituminous coals such as are mined in Illinois, is the chain grate.

#### Chain Grate Stoker Requirements.

The chain grate consists essentially of an endless linked metallic belt. This belt carries the fuel through the furnace, where it is burned, relieves itself of the refuse and returns to the front of the boiler.

A grate of this type must meet certain definite requirements. There must be enough open space, uniformly distributed over the grate surface, to insure a thorough supply of air to all of the coal. These spaces must be so formed that the sifting of the finer coals through the grate is prevented prior to the combustion of the fuel. The grate must clear



itself of all ash and clinkers. For free burning bituminous coals the fuel must remain undisturbed on the grate surface until combustion is complete. Last, and most important, the grate must be so designed that air leakage around and beneath it is kept at a minimum.

Besides these virtues a grate of this type should possess mechanical improvements such as speed variation, depth of fire regulation, and an accessibility to the various parts.

#### The Harrington Stoker.

#### The Grate Surface.

The grate surface proper consists of a series of small castings which match up with one another in such manner that a continuous surface is formed. The air space between adjacent and interlocking bars is dependent upon the size of the bars. The percent air space for any grate, is predetermined dependent upon the kind of fuel to be burned. In assembling the



grate, the clips or bars which will unite to give this air space, are inserted. These grate bars are two inches in width and so designed that they can be slipped over the head of a cast-iron supporting bar or rack, placed transversely to the grate travel. These tracks are bolted to the links of a series of extra heavy semi-steel chains operated through a series of driving sprockets on the front shaft and a set of curved tracks integral with the rear cross girder. Between these two points the chains are supported and guided by steel tracks which engage rollers placed in every link of the chain. The grate surface is entirely self-cleaning, the adjacent sections pulling apart and opening up all air spaces at each turn around the ends.

#### The Chain Tension.

The chain tension is taken up entirely in the series of semi-steel chains as described above. The bars forming the actual grate surface are free to



expand in any direction and are subjected to no stress whatsoever.

#### The Grate Bars.

Due to the fact that the grate bars themselves are free and independently carried on grate racks, any bar can be replaced without removing the tension on the chain and without in any way affecting the adjacent bars. Burned or broken bars can be removed while the stoker is under fire.

#### The Drive.

This stoker may be driven in any one of three ways. First: From a line shaft through a special speed-changing device to a worm wheel in an enclosed housing. Second: From an individual motor attached to the side frame, and driving through a series of enclosed worm gears to the main worm wheel on the front sprocket shaft. Third: By an individual engine attached to the side frame through a similar train of worm gears.



The last mentioned method is the one employed on the stoker from which the thesis tests were taken.

#### Air Seal.

On the particular unit, which was under observation, the grate was sealed on the fire side by over-hanging ledges of brick extending the full length of the chain on both sides. The clearance between these ledges and the grate surface was made a minimum. The ash pit was sealed at the back of the grate by a swinging door which left small space for leakage between it, and the returning grate surface.

#### Draft Gear.

The stoker was equipped for either natural or forced draft. Air was admitted to any or all of three equal zones, on the fire side, by means of dampers placed between the fire and return side of the grate.

Vertical baffles, set transversely to the grate travel and between the moving side of the "belt,"



formed the three rectangular zones. In the bottom of these zones, directly above the returning side of the grate, were located the horizontal natural draft dampers. Air found its way to these dampers through the open (front) end of the ash pit. When these dampers were closed "wind boxes" were formed for the forced draft, which was supplied through vertical dampers at one end of each box.

The forced draft was supplied from an engine-driven blower through a duct which connected with the three zone dampers.

#### The Plant.

The unit tested is located in the power plant of the Armour Institute of Technology, 33rd and Federal streets, Chicago, Illinois. This plant furnishes heat and power to the Institute and a block of apartment buildings. It consists of two - 250 H. P. and one 350 H. P. Stirling water tube boilers. The former are equipped with Green Chain Grate Stokers and the latter with the Harrington



Stoker, upon which this test was made.

The combustion chamber in this unit is about 18 ft. high and extends from the first row of tubes to the coking arch which protrudes inward from the front of the boiler about 3 ft. and about the same distance above the normal fuel surface. There are two passes, one down and one up, between the chamber and the breeching.

The breeching is a straight pass from the rear of the setting into the base of the stack. A butterfly damper, controlled hydraulically from the guage board, is located here.

The stack is situated behind this unit. The other boilers unite into an uptake which leads to another side of the stack at a different level. The chimney is constructed of building brick and sets on an octagonal base 16 ft. in diameter. It has a 7 foot internal diameter and is 175 feet high, measured from the boiler room floor.



The auxiliaries used with this boiler are: any or all of three horizontal reciprocating feed pumps, cross connected; open feed heater and condenser; and a single barrel piston air pump. The feed pumps are:

- |     |              |          |
|-----|--------------|----------|
| (1) | Smith Vaile. | Duplex.  |
| (2) | Worthington. | Duplex.  |
| (3) | American.    | Simplex. |

The combination feed heater and condenser is of the old Webster type.

Besides the fittings required by law this unit has several modern appurtenances which, together with the testing apparatus, insured, at least, good relative data.

Diamond soot blowers; a Uehling CO<sub>2</sub> recording apparatus; Builders Iron Foundry venturi meter; Bristol recording feed water thermometer and flue gas pyrometer, and a G. E. steam flow meter compose the extra equipment.

The coal for the plant is delivered in car load lots. The cars are unloaded by hand and the coal sent to the boiler room floor through a chute.



It is shoveled from here into the hopper located in front of the boiler above the stoker.

The ashes are hoed from the pit and then hauled outside.



### Purpose of Test.

The object of this work is to present the results obtained and conclusions drawn from a thorough investigation into the performance of a Harrington chain grate stoker installed under a 350 H. P. Stirling boiler in the power plant of the Armour Institute of Technology.

Standard evaporative tests were conducted to determine the efficiency of the boiler and furnace under the conditions existent. The performance and action of the grate in meeting and responding to the fluctuations in load, under which the boiler normally operates, were observed.

### Method of Procedure.

In starting every run the boiler was taken over after it had been working several hours under its operating load. Consequently, the conditions were adjusted to be as constant as the variation in the load would permit. The ashes were drawn



and the water level marked on the gage glass. The coal in the hopper was then leveled to a position that was easily duplicated at the end of the run.

These operations were completed just before the time set for starting the run. All coal subsequently fired and all water fed to the boiler, during the run, were weighed. At regular intervals during the test the following observations were made and recorded: steam pressure, temperature of steam in calorimeter, outside temperature, room temperature, feed water temperature, flue gas temperature, draft intensity and flue gas analysis. At the close of the run the water was brought back to the original level; the coal in the hopper to the same position as at starting and the ashes drawn and weighed. A sample of the ashes was taken for analysis. Along with each set of observations the amount of coal fired during the previous interval was noted.

The coal was dumped in the hopper in basket lots of forty pounds. The weight on the scale beam was fixed so that the desired amount of coal



balanced the arm. This phase of the work was done by hand.

From each basket a small amount of coal was taken for a sample. These samples were all placed in another basket. At the end of the run the accumulated sample was spread on the floor, thoroughly mixed, and all lumps broken. It was then quartered and the opposite quarters retained and mixed again. This process was repeated until the sample was about pin-head size and enough to fill a quart fruit jar. The final sample was sealed to prevent moisture loss before a proximate analysis was made.

The sample of coal in the jar was further ground in a mortar and then sifted through a 200 mesh sieve. The coal was then ready for analysis.

The ash sample was taken from the ash pile at the times when they were hauled and treated as was the coal sample.

The volatile combustible in the coal was determined by applying heat, for seven minutes, to a crucible containing the sample. The loss in weight



was taken as the volatile combustible.

The moisture was found by placing a sample of coal in an electric oven, at a temperature of 220 deg. fahr., for one hour.

To determine the ash content the fuel was heated, exposed to the air, until there was no further reduction in weight.

The heating value of the fuel was found in the fuel as fired. A Mahler bomb was used in the usual manner.

The combustible in the ash was found by heating the ash sample until no further reduction in weight was noticed.



### Apparatus and its Calibration.

The apparatus used consisted of a scales and a basket for weighing and lifting the coal to the hopper; steam gage; calorimeter for determining the quality of the steam; four thermometers for determining room, outside, feed water and calorimeter temperatures; a venturi meter for measuring the water fed to the boiler; draft gages; revolution counter for grate; pyrometer for obtaining the flue gas temperature and an Orsat apparatus for analysing the flue gas, in addition to the usual apparatus for analysing coal and ash and determining its heat value.

### Calibration of Apparatus.

#### Steam Gage.

The 8 inch Crosby steam gage was tested on a Crosby deadweight machine and after adjustment found to be correct within the limits used on the test (90 - 125 lbs./sq. in.).



### Scales.

Two Fairbanks scales were used; one for weighing coal, the other in the calibration of the venturi meter. These were tested and found to be correct by means of standard 50 lb. weights.

### Venturi Meter.

Incorrect weights of coal and water are the predominating errors in most boiler tests. The method of weighing coal, as previously described, the authors believe to be as accurate as was consistent with the other observations taken. Due to physical obstructions it was impossible to weigh the feed water. In lieu of this method the venturi meter was used.

It was first over-hauled; all the moving and wearing parts cleaned, oiled, and in some instances parts replaced with new ones. The pipe lines to the venturi tube were then given a drop test and made tight. Rather than attempt to adjust the instrument to read correctly a calibration curve was drawn.



The calibration consisted of several runs at various rates of flow. The water after passing through the tube was bi-passed around the boiler check and weighed in a tank. From the time interval in feeding 1000 lbs. of water in the tank the rate of flow was computed. From this actual flow, and the recorded flow on the meter, points were located on the curve.

A stop watch connected to the scale beam left personal equation out of the start and finish of the run. As noted from the curve the error was consistent.  
Steam Meter.

The steam flow meter was calibrated with the venturi meter. The readings on the steam meter were averaged for the period of an hour and compared with the reading on the venturi.

The steam flow meter indicates the weight of steam leaving the boiler, and the venturi registers the water entering. By holding the level of the water in the boiler constant the water entering should be the same as that leaving.



The calibration of the steam meter was carried on over two eight hour periods to obtain a fair average.

#### Carbon Dioxide Recording Apparatus.

The Uehling CO<sub>2</sub> recording apparatus was calibrated by means of an Orsat apparatus. The charge for the Orsat was drawn from a tap in the line leading to the CO<sub>2</sub> recorder in order to obtain as nearly as possible a sample such as was going through the Uehling recorder.

#### Flue Gas Pyrometer.

The Bristol flue gas pyrometer was calibrated against a standard electric pyrometer (tested by B. of S.) between 300 and 700 degrees Fahr. The terminals of the pyrometer were inserted together in an electric oven and a double set of readings taken; one while the temperature was rising, the other while falling. The instrument was then adjusted so that accurate readings were obtained thereby eliminating a calibration curve.



**Thermometers.**

The thermometers used were borrowed from the Physics Department of the Armour Institute. They had all been calibrated and their error too small to affect in any way the data taken.



### Results and Sample Calculations.

The results of the tests are divided into two parts; the first three runs being conducted with the grate operating under the original setting; and the remaining five with a setting modified to correct some of the faults found to exist.

### Changes in Furnace and Grate.

These were two outstanding faults in the original furnace setting; one being the position of the ignition arch, and the other, the action of the forced draft beneath the grate surface.

The general dimensions of the original furnace setting show the position of the arch. There was very little clearance between the arch and top of fuel bed on the grate. According to the accepted theory, the radiant energy of the live fuel is reflected back by the ignition arch upon the green fuel following it, causing the volatile gases to be driven off and leaving the coke. This action was prevented by the proximity of the fuel and arch



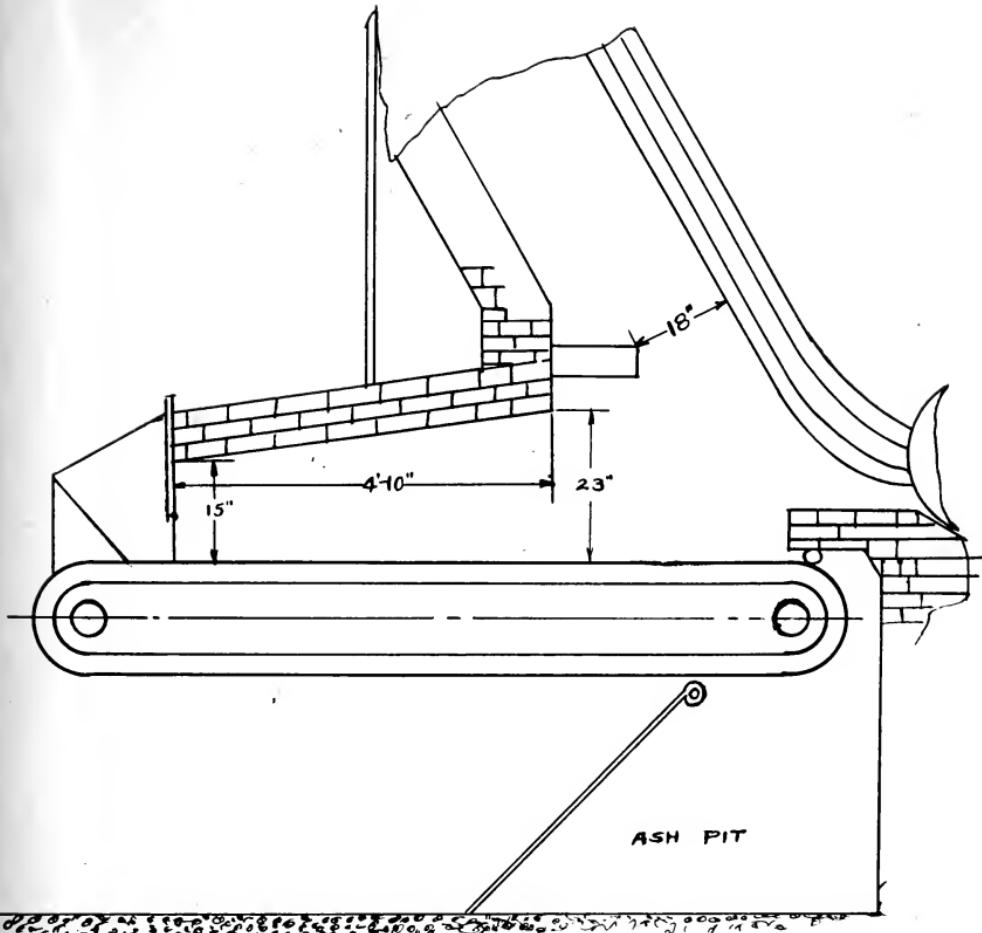


DIAGRAM OF OLD FURNACE SETTING .



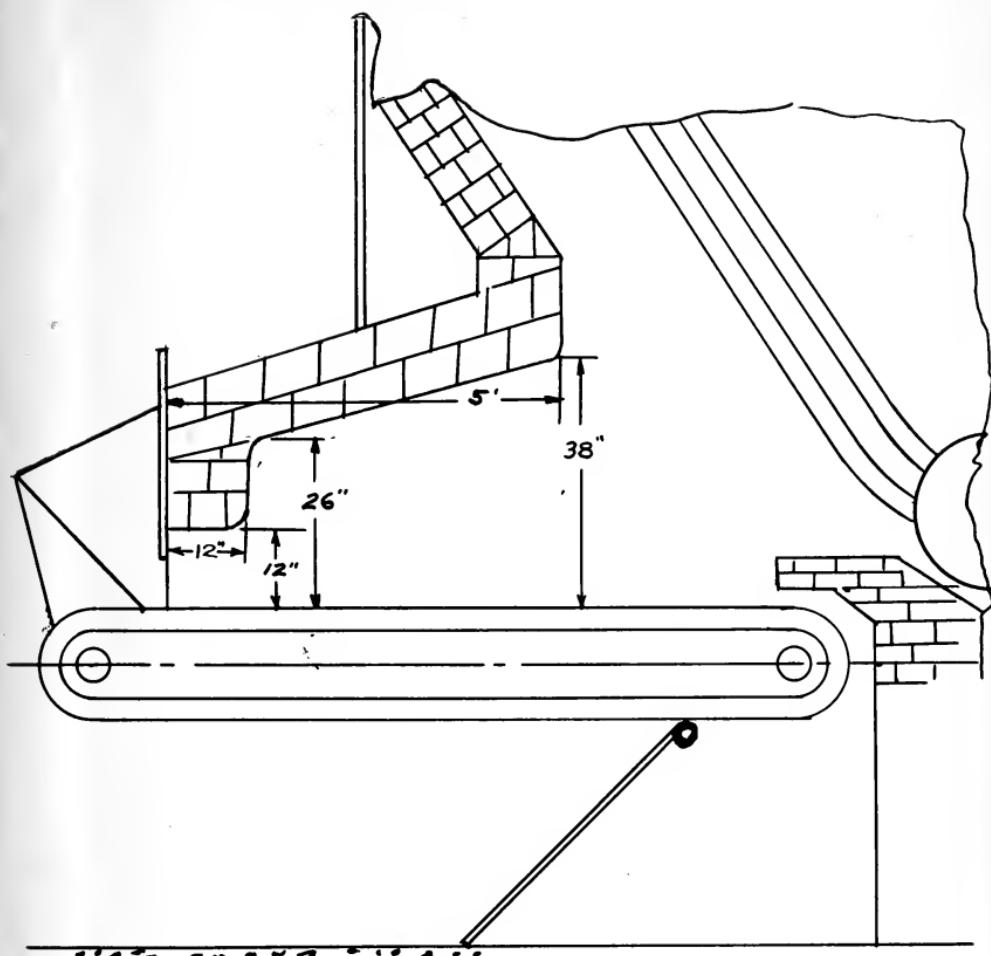


DIAGRAM OF NEW FURNACE SETTING.

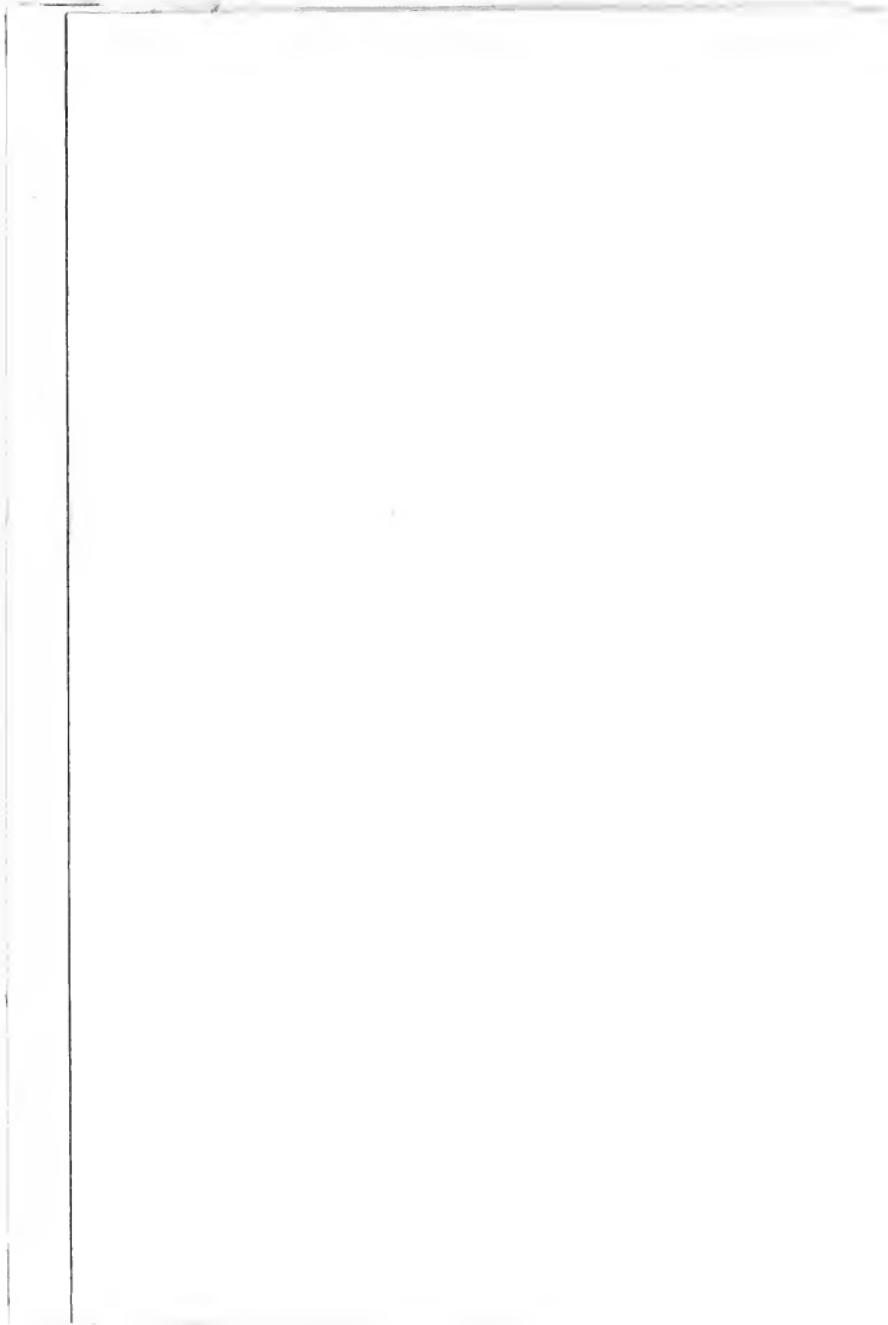


and resulted in one-third of the grate being rendered useless for the burning of fuel.

The raising of the arch overcame this defect in the setting construction.

It was impossible to keep an even fire using forced draft. It was necessary to rake coal from the side where the air entered over to the opposite side. Due to the shallowness of the air compartment velocity was imparted to the air causing it to flow to the opposite side of the grate. Vertical baffles placed in the chamber served to break up the current of air and distribute it more evenly as evidenced by the more even burning of the fire.







350 H.P. STERLING BOILER  
 HARRINGTON CHAIN GRATE.  
 9FT.LONG 7FT.WIDE 63SQ.FT.AREA  
 WATER HEATING SURFACE 3500  
 RATIO OF HEATING TO GRATE 55.5:1

RUN NO.		1	2	3	4	5	6	7	8
DURATION OF RUN	HOURS	4 $\frac{1}{2}$	5	8	5	8 $\frac{1}{4}$	8	8	8
<b>AVERAGE PRESSURES:-</b>									
BAROMETER	INS. MERCURY.	29.60	29.60	29.59	29.58	29.16	29.06	29.84	29.80
STEAM GAUGE LB. PER SQ. IN.		101	99.5	97.2	110.63	97.09	112.4	97.87	97.8
ABSOLUTE STEAM PRESSURE LBS PER SQ IN.		115.5	115	111.8	125.13	111.39	126.63	112.52	112.3
DRAUGHT	{ OVER FIRE INS. WATER #2 COMPARTMENT INS. WATER #3 COMPARTMENT INS. WATER					-152	-146	-12	-115
		.055	.050	.070		.215			
						.168			
<b>AVERAGE TEMPERATURES:-</b>									
EXTERNAL AIR	DEG. FAHR.	31	37	35	50	45	55	56	57
BOILER ROOM	DEG. FAHR.	55	65	57	61	68	75	76	77
FLUE	DEG. FAHR.	408	440	420	401	379	409	400	395
FEED WATER	DEG. FAHR.	180	194	179.9	206	178.7	204	196.7	187.0
STEAM	DEG. FAHR.	338.4	338.1	335.9	344.4	335.6	345.3	336.5	336.3
<b>TOTAL FUEL</b>									
COAL AS FIRED	LBS.	6060	7880	9760	8120	11800	12417	9520	9170
DRY COAL CONSUMED	LBS.	5210	6820	8979	7250	10762	11050	8463	8150
TOTAL REFUSE DRY	LBS.	1162	1368	1550	950.5	1928	1154	806	827
TOTAL REFUSE DRY PERCENT DRYCOAL		22.3	20	17.29	13.1	16.4	10.4	9.54	10.18
COMBUSTIBLE CONSUMED	LBS	4048	5452	7429	6300	8834	9896	7657	7323
COMBUSTIBLE CONSUMED PERCENT DRYCOAL		77.5	80	82.8	87	75.25	88.5	90.5	89.9



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FUEL PER HOUR										
COAL AS FIRED	LBS.	1484	1576	1220	1624	1475	1552	1190	1141	
DRY COAL	LBS.	1275	1564	1122	1450	1345	1381	1058	1019	
COMBUSTIBLE CONSUMED	LBS.	990	1090	928	1260	1104	1237	957	913	
DRY COAL PER SQ.FT. OF GRATE	LBS.	20.2	24.8	17.8	23	21.35	20.9	16.8	16.18	
TOTAL WATER										
QUALITY OF STEAM	PERCENT	97	97.7	97	96.7	96.8	97.2	97.2	97.1	
APPARENTLY EVAPORATED	LBS.	41886	54830	71268	73750	95700	112800	91200	85600	
ACTUALLY EVAPORATED INTO DRY STEAM	LBS.	40629	53560	69124	71537	92644	109641	88646	83117	
FACTOR OF EVAPORATION		1.0453	1.0366	1.0426	1.0171	1.0440	1.0243	1.0180	1.0386	
TOTAL FROM AND AT 212 DEG.	LBS.	42469	55528	72068	72753	96720	112305	90241	86325	
WATER PER HOUR.										
APPARENTLY EVAPORATED	LBS.	10250	10966	8908	14750	11600	14100	11400	10700	
ACTUALLY EVAPORATED	LBS.	9930	10713	8640	14307	11200	13705	11080.7	10389	
EVAPORATED FROM AND AT 212 DEG. FAHR.	LBS.	10400	11105	9008	14550	11720	14038	11280.1	10790	
EVAPORATION										
PER POUND OF FUEL AS FIRED										
APPARENT	LBS.	6.91	6.95	7.29	9.09	8.11	9.06	9.58	9.34	
ACTUAL	LBS.	6.70	6.80	7.08	8.80	7.85	8.81	9.21	9.06	
EQUIVALENT FROM AND AT 212 DEG.	LBS.	7.00	7.05	7.38	8.95	8.20	9.05	9.49	9.40	
PER POUND OF DRY COAL										
APPARENT	LBS.	8.03	8.04	7.94	10.17	8.90	10.20	10.79	10.51	
ACTUAL	LBS.	7.79	7.85	7.07	9.85	8.60	9.91	10.46	10.20	
EQUIVANT FROM AND AT 212 DEG.	LBS.	8.15	8.15	8.03	10.02	8.99	10.15	10.65	10.60	
PER POUND OF COMBUSTIBLE CONSUMED										
APPARENT	LBS.	10.35	10.05	9.59	11.70	10.82	11.40	11.90	11.69	
ACTUAL	LBS.	10.03	9.80	9.30	11.35	10.50	11.10	11.58	11.35	
EQUIVALENT FROM AND AT 212 DEG.	LBS.	10.49	10.19	9.70	11.55	10.95	11.39	11.8	11.79	
PER SQ. FOOT OF HEATING SURFACE PER HOUR										
ACTUAL	LBS.	284	306	246	4.08	3.21	392	3.18	2.96	
EQUIVALENT FROM AND AT 212 DEG.	LBS.	2.975	317	257	4.15	3.35	4.01	3.22	3.08	



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HORSE POWER									
ON BASIS 34 1/2 LB. EQUIV. EVAP. PER									
HOUR	H.P.	301	322	261	420	340	407	371	312.5
COMMERCIAL BUILDERS RATING		350	350	350	350	350	350	350	350
PERCENT OF BUILDERS RATING		85.5	92	74.5	120	97.2	116	106	88.4
EFFICIENCY OF BOILER AND GRATE		60.5	58.3	61.5	70.6	72.5	70.2	73.5	72.9
ANALYSIS									
ANALYSIS OF FUEL AS FIRED									
FIXED CARBON	PER CENT	48.79	53.5	55.5	46.9	49.95			55.6
VOLATILE MATTER	PER CENT	23.48	25.00	23.50	28.50	24.60			25.0
MOISTURE	PER CENT	14.23	8.00	8.00	8.25	8.80	11.1	11.1	8.3
ASH	PER CENT	13.50	13.50	13.50	16.35	16.65			11.1
COMBUSTIBLE	PER CENT	72.27	78.5	78.5	75.40	74.55			80.6
CALORIFIC VALUE OF FUEL AS FIRED									
	B.T.U.	11256	11730	11640	12200	10980	12500	12500	12500
ANALYSIS OF FLUE GAS									
CO <sub>2</sub>	PER CENT	7.80	7.76	7.66	9.84	7.75	8.87	7.34	7.88
CO	PER CENT							.40	.40
O <sub>2</sub>	PER CENT							10.76	10.12
DEPTH OF FIRE	INS.	7"	6	6	7	7	6 1/2	6	5
SPEED OF GRATE	INS. PER MIN.	2.074	2.203	1.765			2.01	1.95	1.165
POSITION OF DAMPER		WIDE	WIDE	WIDE	WIDE	WIDE	1/2 OPEN	1/2 OPEN	3/4 OPEN



### Sample Calculations

April 15, 1920.

Duration of Run	8.25 hours
Grate Surface	63 sq. ft.
Water Heating Surface	3500 sq. ft.
Ratio of heating to Grate Surface	55.5 to 1

### Average Pressures.

Barometer	29.16 ins. Hg.
Steam Gauge	97.09 lbs./sq.in.

Absolute Steam Pressure:-

$$\frac{29.16 \times 13.6 \times 62.5}{12 \times 144} = 14.3 \text{ lbs. per sq. in.}$$

13.6 = density of mercury

62.5 = wt. of cu. ft. of water

$$97.09 + 14.3 = 111.39 \text{ lbs./sq.in.}$$

### Average Temperatures

External air	45 deg. F.
Boiler Room	68 deg. F.
Flue	379 deg. F.
Feed Water	178.7 deg. F.



## Total Fuel.

Coal as Fired    11800 lbs.

## Dry Coal Consumed:-

$$\frac{11,800 \times (100 - 8.8)}{100} = 10,762 \text{ lbs.}$$

8.8 moisture per cent

Total Refuse,dry                                    1,928 lbs.

Total Refuse, dry (per cent of dry coal)

$$\frac{1928}{10762} \times 100 = 16.4\%$$

## Combustible Consumed:-

$$10762 - 1928 = 8834 \text{ lbs.}$$

Combustible Consumed (per cent of dry coal):-

$$\frac{8834}{10762} \times 100 = 75.25\%$$

## Fuel Consumed per Hour.

## Coal as Fired:-

$$\frac{11,800}{8.25} = 1475 \text{ lbs.}$$



Dry Coal:-

$$\begin{array}{r} 10,762 \\ \hline 8.25 \end{array} \quad 1345 \text{ lbs.}$$

Combustible Consumed:-

$$\begin{array}{r} 8634 \\ \hline 8.25 \end{array} \quad 1104 \text{ lbs.}$$

Dry Coal per sq. foot of Grate

$$\begin{array}{r} 1345 \\ \hline 63 \end{array} \quad 21.35 \text{ lbs.}$$

Total Water.

Quality of Steam:- 96.8%

$$x_r + q_i = x_z r_z + q_z + c_p t_s \quad x_z = 1.0$$

$$x_r = \frac{r_z - q_i + q_z + c t}{r_z} \quad \text{at } 14.3 \text{ lb./sq.in. : -}$$

Substituting in the above,

$$x_r = .968$$

$$r_z = 970.4$$

$$t_s = 233 - 212 = 21 \text{ deg.F.}$$

$$q_z = 180$$

$$c_p = .48$$

233 deg.F. was average

at 119.39 lbs./sq.in. : -

temperature of steam in

$$r_z = 881.9$$

calorimeter.

$$q_i = 306.2$$



Apparently Evaporated.

Venturi at start of run	509,145.0 lbs.
Venturi at close of run	509,230.5 lbs.
Water used during run	85,500 lbs.
Water per hour    85500	
<u>          </u>	10,350 lbs.
8.25	
Corrected 11,600 lbs.	
11,600 X 8.25	95,700 lbs.

Actually Evaporated into Dry Steam:-

$$95,700 \times .968 \quad 92,644 \text{ lbs.}$$

Factor of Evaporation:-

$$f = \frac{x, r, + q_1 - q_2}{970.4} \quad x, = 96.8$$

at 111.39#/sq.in. :-

$$f = 1.0440 \quad r, = 881.9$$

$$q, = 306.2$$

$$q_2 = 178.7 - 32 = 146.7$$

Total from and at 212 deg. F.

$$92644 \times 1.0440 \quad 96,720 \text{ lbs.}$$



Water per hour apparently evaporated:-

95700	
<hr/>	
8.25	11,600 lbs.

Evaporation per pound of Coal as Fired,

Equivalent from and at 212 deg. F. :-

96720	
<hr/>	
11800	8.20 lbs.

Per Pound of Dry Coal,

Equivalent from and at 212 deg. F. :-

96720	
<hr/>	
10762	8.99 lbs.

Per Pound of Combustible Consumed,

Equivalent from and at 212 deg. F. :-

96720	
<hr/>	
8834	10.95 lbs.

Per Square Foot of Water Heating Surface per Hour,

Equivalent from and at 212 deg. F. :-

11720	
<hr/>	
3500	3.35 lbs.



Horse Power.

On basis of 34.5 lb. equivalent evaporation per hour:-

$$\frac{11720}{34.5} \quad 340 \text{ B.H.P.}$$

Ratio of Commercial to Builder's Rating:-

$$\frac{340}{350} \quad X 100 \quad 97.2\%$$

Efficiency:-

$$\frac{8.20 \times 970.4}{10,980} \quad X 100 \quad 72.5\%$$



ACTUAL  
WEIGHT  
IN  
1000 LB.

VENTURI METER  
CALIBRATION CURVE

20

19

18

17

16

15

14

13

12

11

10

10

11

12

13

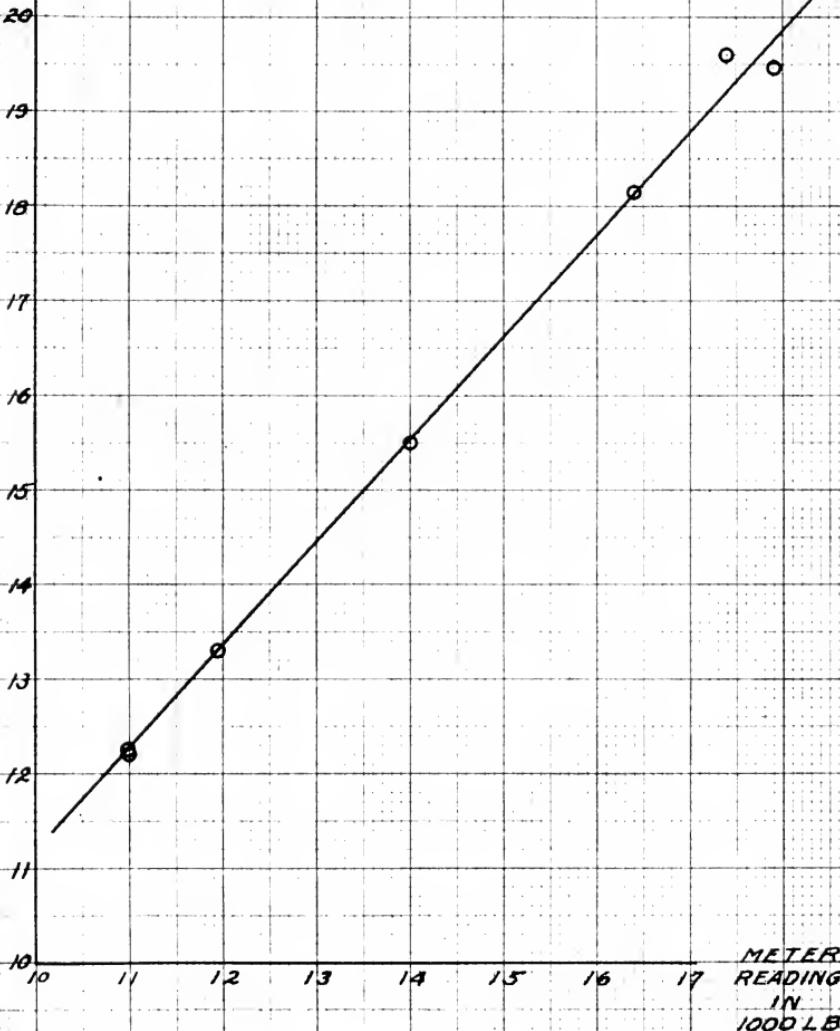
14

15

16

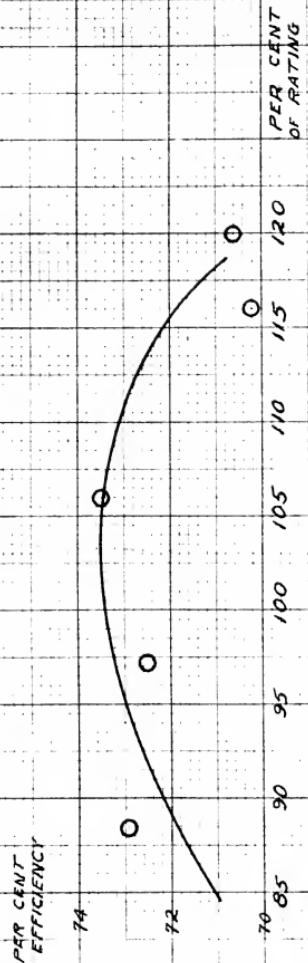
17

METER  
READING  
IN  
1000 LB.

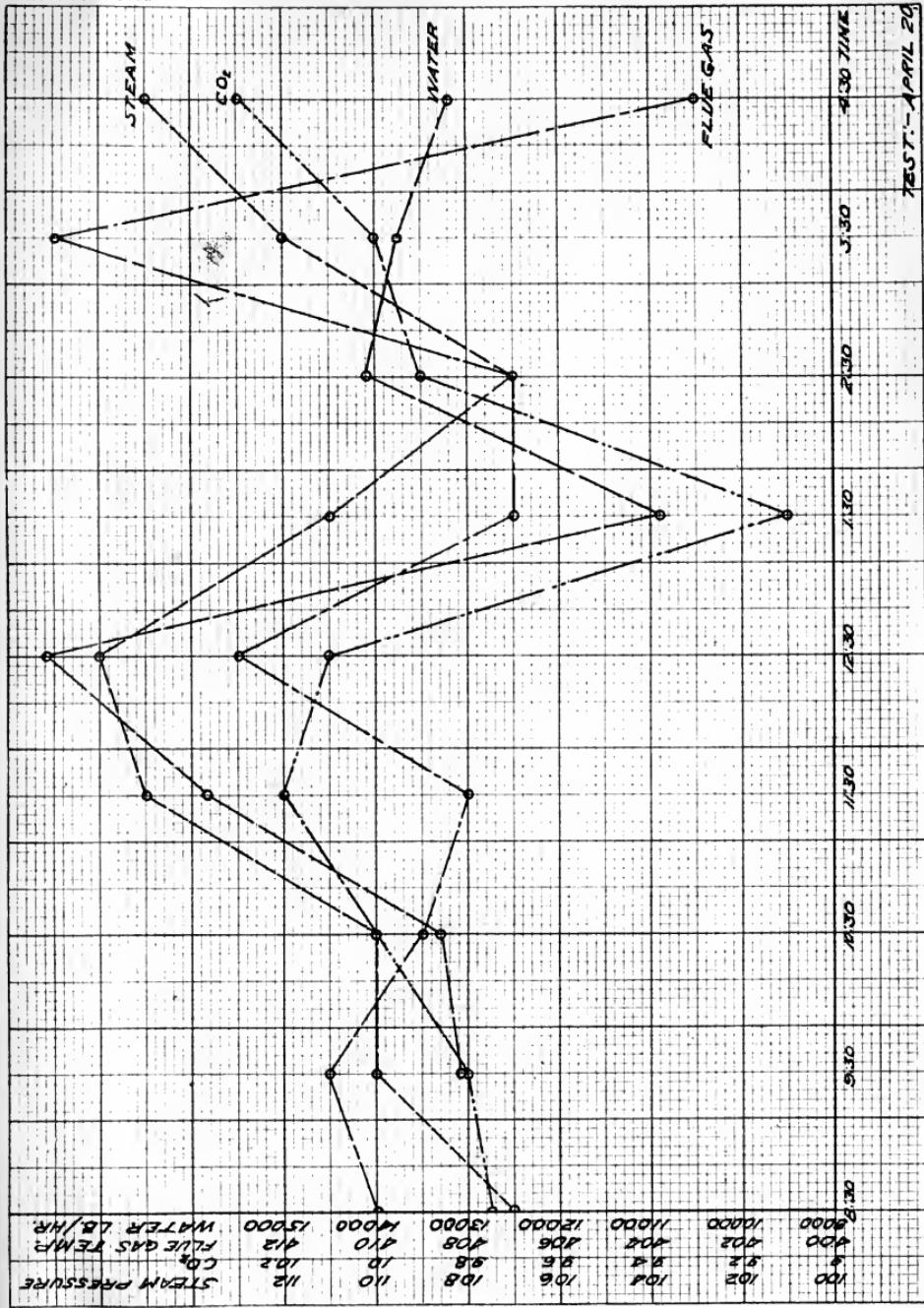




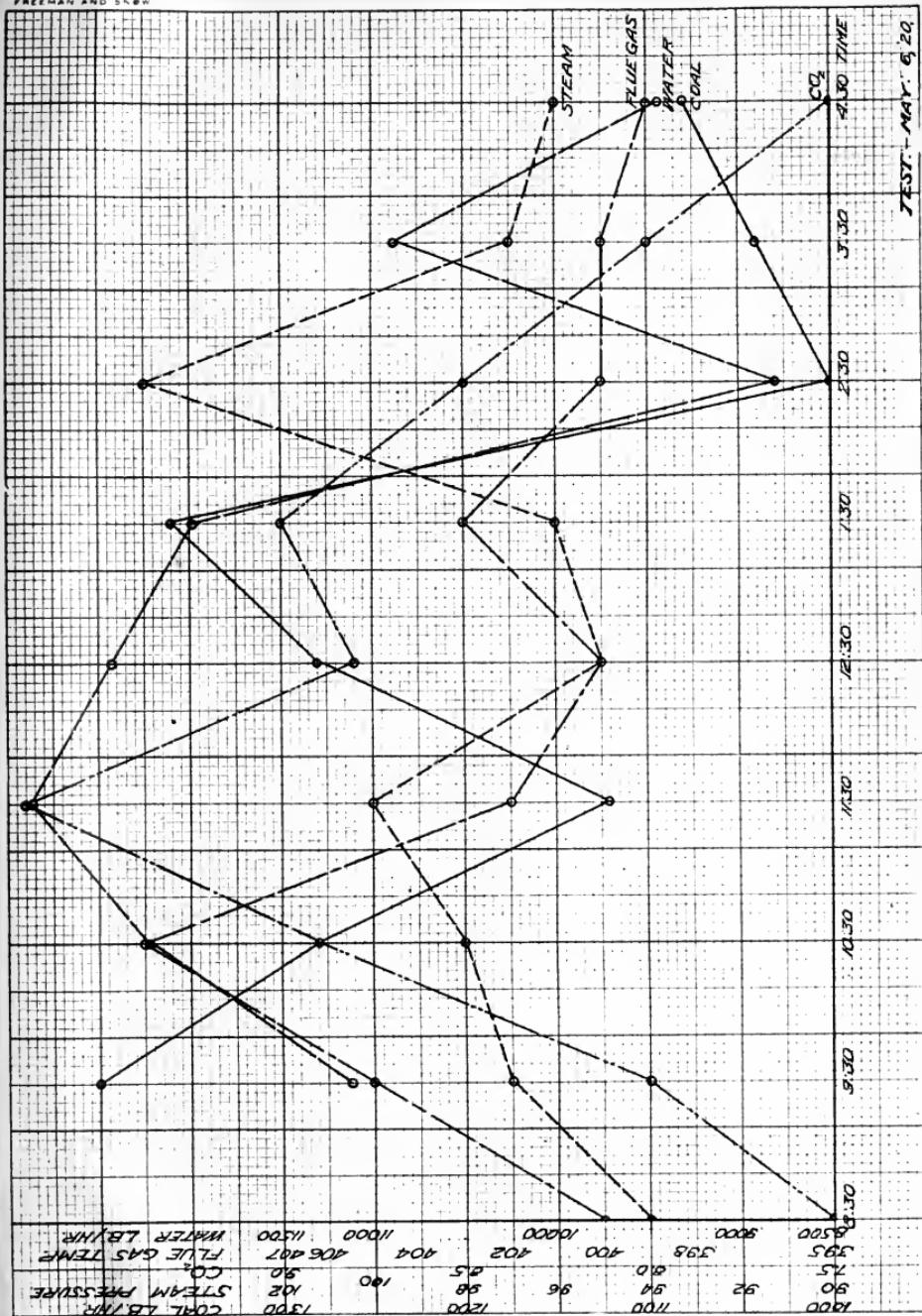
## EFFICIENCY-CAPACITY CURVE



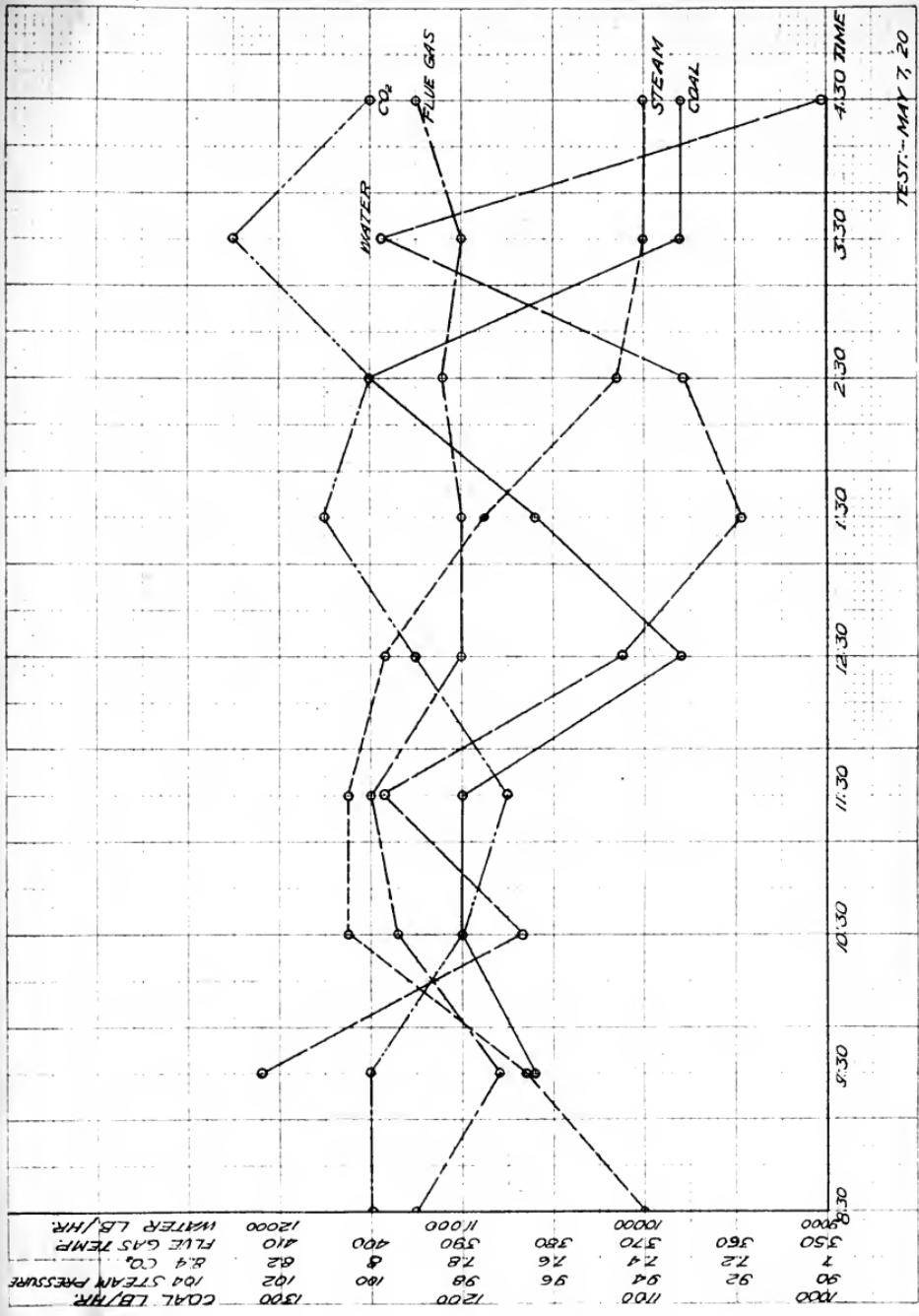














**PART TWO.**

Which contains the conclusions as deduced  
from the results.



### Conclusions.

In presenting these conclusions the authors are merely setting forth their opinions, which are by no means incontestable.

At the times when tests were conducted the entire load of the plant was thrown on the unit under observation. The great fluctuations in load (as noted by steam meter readings), and the slight variation in steam pressure shows the grate adaptable to such conditions. (In the data the steam pressure has considerable variation in the first five runs. This was due entirely to the coal. The grate was designed to handle #3 wash nut (Illinois) and during the last three runs this was used. However, because of the impending fuel famine, at the time the first five runs were made it was necessary to burn screenings, which ran so low in heat value that the maximum speed of grate and intensity of draft would not maintain the desired working pressure).



Mechanically the grate is very satisfactory.

Its flexibility to meet large fluctuations in load has already been mentioned. The changing of grate bars is a very simple operation and was performed by the authors with the grate under fire. No trouble was encountered with clinkers, and the sifting of the finer fuels through to the ash pit was negligible.

The most prominent defect evidenced in the operation of this unit was the low carbon dioxide content in the flue-gas. Despite the great attention given the draft, its intensity and distribution, the highest individual CO<sub>2</sub> content recorded was ten percent.

The changes made on the setting resulted in an increase of from sixty percent on the old setting to seventy-two on the new, over all efficiency. At the time these changes were made an inspection of the combustion chamber, side walls, passes and breeching was made. The brick work throughout the boiler setting, including the main baffles, was found to be intact and practically air tight. However, despite



the most careful manipulation of the various dampers there was at all times an excess of air. As the ash pit door shut off all air supply to the back of the grate, the only remaining entrances left for the air to reach the flue was through, around and between the moving sides of the grate. Although no holes large enough to be seen were left uncovered, the authors feel that there was a leakage through the grate and green coal due possibly to the peculiar design of the bars.

The raising of the coking-arch had no appreciable effect upon the CO<sub>2</sub> content. The increase in efficiency was gained by completing combustion in the earlier passes as evidenced by the decrease in flue-gas temperature (440-400 deg. F.). Due to the force of circumstances the last few runs were conducted at a low rating. The fire covered only about one-third to one-half of the grate. Under these conditions the CO<sub>2</sub> ran between 7.5 percent and 7.8 percent.



It may be that the forced draft air, which passes into the "wind-boxes" and carries itself to the opposite side of the grate due to its kinetic energy, partially by-passes itself around the live fuel at the grate's side. Improvised vertical baffles set in the center of the "wind-boxes" converted part of this kinetic energy into velocity upwards through the fire and perhaps a scientific arrangement of such baffles would entirely eliminate this difficulty.



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